Altair | HyperWorks®

Toward Better Failure Prediction for Crash Simulations using HPC

Overview

PSA Peugeot Citroën collaborated with Altair, Ecole Polytechnique Laboratoire de Mécanique des Solides (LMS) and PRACE to perform a study of automotive crash rupture simulations, investigating ways to improve material failure criteria and better predict cracks. Using Curie, one of the ten most powerful supercomputer in the world, designed by the company BULL and operated by them at Très Grand Centre de Calcul du CEA (TGCC), project engineers ran huge (15M element) solid models of some component using a very fine mesh in order to simulate material failures. The massive parallelism enabled by Altair RADIOSS on the Curie system achieved unprecedented results, with levels of performance that would not have been possible on a standard computer or cluster.

Business Profile

The second largest carmaker in Europe, PSA Peugeot Citroën (PSA) recorded sales and revenue of €54 billion in 2013. With its world-renowned brands, DS, Peugeot and Citroën, PSA sold 2.8 million vehicles worldwide in 2013, of which 42% outside Europe. PSA is a European leader in terms of CO_2 emissions, with an average of 115,9 grams of CO_2/km in 2013. PSA has sales operations in 160 countries and is also involved in financing activities (Banque PSA Finance) and automotive equipment (Faurecia).


CURIE Supercomputer at CEA/TGCC-GENCI

Challenge

As automotive regulations impose lower and lower CO_2 emission levels, manufacturers face serious challenges in decreasing design structure mass by using higher strength-to-weight ratio materials. However, introducing new materials into a design process is not a simple undertaking; design rules and numerical tools must evolve to comprehend the characteristics -- and evaluate the potential failures – of such materials. Otherwise, there is risk in delaying production awaiting reliable design direction from simulation, or (worst case) having to redesign a part late in the design cycle. In addition, due to the large, nonlinear deformations involved in simulating crash or rupture events, proper material failure criteria is essential to results accuracy. Evaluating new materials, which by definition lack the testing and refinement over time of conventional materials, also typically results in applying higher safety factors for the design which can lead to oversizing of structural parts.

To improve its knowledge in assessing predictive rupture models, and to identify a viable solution for testing ruptures on a massive scale, PSA engaged with Altair through PRACE to evaluate the robustness of advanced failure criterion for steel sheets using RADIOSS, the market-leading analysis solver for crash simulation in Altair's HyperWorks CAE software suite.

PSA PEUGEOT CITROËN

BULL   ÉCOLE POLYTECHNIQUE ParisTech   PRACE
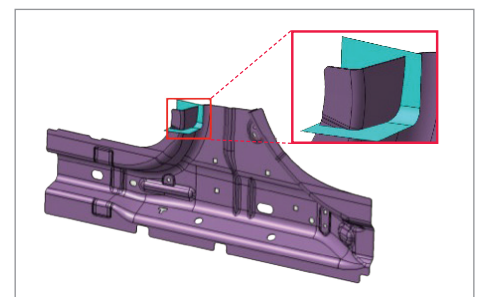
B-pillar Reinforcement CAD

"This type of project required supercomputing power and software performance on a previously unprecedented scale. Thanks to Altair, LMS, PRACE teams and BULL, we are confident in the capabilities of RADIOSS to handle such huge model and now we target to extend to the simulation in real crash conditions using a full car model and some refined components."

Laurent Caplain
CAE crash specialist for car body & equipments
PSA Peugeot Citroën

Solution

First, Altair engineers ported RADIOSS to Bullxmpi for the Curie supercomputer allocated to the study. This porting included the optimization of the setup of RADIOSS under Bullxmpi to obtain ideal performance.

The efficiency of the solution based on Bullxmpi was evaluated and improved using industrial car crash models ranging from 1 to 10 million of elements.

Then, two specific models were developed to study rupture of a B-pillar component with mesh size requirement of 75μm element length.
- A first model by Altair with 15 million of elements was used to assess scalability of the code up to 8192 cores. Project engineers were very satisfied by the performance results. Hybrid MPI OpenMP parallelization helps to maintain high efficiency of the code. With larger models, the code should scale beyond 8192 cores.
- A second model was built by PSA, with mesh optimization reducing element number to 10 million and increasing critical time step to help reducing total number of cycles. This final model for 100ms simulation is expected to run in less than 60 hours using 2048 cores of Curie according to partial runs made up to 10ms during this preparatory study.

Altair had to optimize the code to handle the large simulation models, especially contact treatments inside the very fine mesh part; the project also required optimizing several I/O treatments, and engineers intensively used Intel tools like Vtune Amplifier to localize algorithms that needed to be improved. These optimizations helped Starter performance and were also useful for Engine performance related to contact sorting.

In addition, Altair engineers implemented a specific material law and a rupture model in RADIOSS, which was developed through an "Industrial Fracture Consortium" including MIT, Ecole Polytechnique and industrial partners like PSA. The implementation of both law and model was validated with respect to tests on specimen and results of the original implementation by Ecole Polytechnique (LMS). Domain decomposition algorithm was tuned to optimize this material law regarding parallel efficiency.
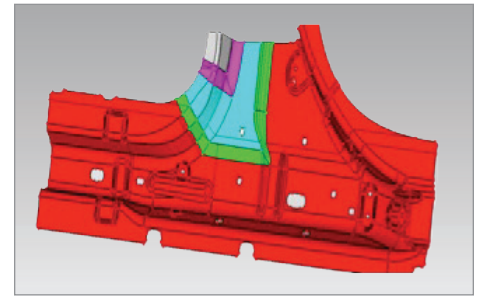
B-pillar Reinforcement Mesh
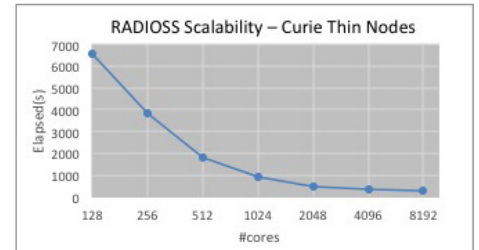
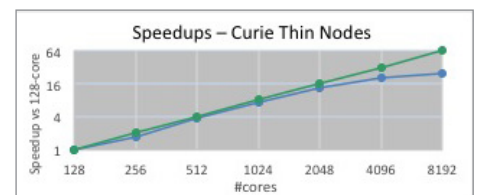*RADIOSS Scalability Study*

Results/Benefits

PSA was pleased with the outcome of the study -- without access to this type of large scale supercomputer system it would have been impossible to consider running such a large simulation problem in a reasonable amount of time.

Key outcomes:
- Validated readiness of the RADIOSS code to handle very large models of several millions of solid elements
- Proved scalability of the code up to 8,192 cores and beyond -- tested up to 16,384 cores for the very first time
- Implemented and validated a new material law and rupture model representing the state of the art for fracture modeling, in collaboration with PSA and Ecole Polytechnique (LMS).

The achievements obtained during this project help companies like PSA to be ready to handle increasingly complex simulations and to evaluate future needs more precisely in term of computational resources for evolving rupture simulation projects. The organizations involved plan to continue this work via a regular PRACE project to study the behavior of the rupture of this B-pillar component as well as some other components through a full vehicle crash simulation.

We acknowledge PRACE for having awarded us access to resource machine Curie based in France at TGCC/CEA.

RADIOSS Speedup Curve